CLAIMS

We claim:

1. A micro-cavity laser comprising:

a. A fiber waveguide, said fiber waveguide having a tapered coupling region, said tapered coupling region being positioned between said first end and said second end of said fiber waveguide;

b. A micro-cavity optical resonator, said micro-cavity optical resonator being arranged so as to provide optical coupling between said tapered coupling region of said fiber and said micro-cavity optical resonator, said micro-cavity optical resonator having at least one optical resonance at a desired frequency output, said micro-cavity including an active medium capable of providing optical gain upon pump excitation; and,

c. At least one laser pump, the output of said laser pumps being optically connected to said first end of said fiber waveguide to couple optical pump power into said resonator to excite at least one resonance to pump said active medium, and induce lasing action such that laser output power is coupled to said fiber waveguide.

2. A micro-cavity laser of Claim 1 further including a second fiber waveguide, said second fiber waveguide having a coupling region between a first end and a second end of said second

fiber waveguide, said second fiber waveguide being optically coupled to said micro-cavity optical resonator.

3. The micro-cavity laser of Claim 2 further including a second set of at least one laser pumps, the output of at least one of said second set of laser pumps is optically connected to said first end of second fiber waveguide and the output of said second set of laser pumps excites at least one resonance in said micro-cavity optical resonator and thereby pumps the active medium to induce lasing action.

4. The micro-cavity laser of Claim 3 wherein the output of at least one of said second set of laser pumps excites at least one resonance in said micro-cavity optical resonator at a frequency different from the resonance excited by the output of said laser pumps optically connected to said first fiber waveguide.

5. The micro-cavity laser of Claim 2 wherein the said first fiber waveguide and said second fiber waveguide are optically coupled to the same micro-cavity resonances.

6. The micro-cavity laser of Claim 5 wherein the said first fiber waveguide preferentially couples laser pump power from said fiber waveguide to the micro-cavity to attain lasing and

said second fiber waveguide preferentially couples laser output power from said micro-cavity to said second fiber waveguide.

7. The micro-cavity laser of Claim 1 wherein said micro-cavity optical resonator is one of a microsphere, disk, ring, and racetrack.

8. The micro-cavity laser of Claim 1 wherein said micro-cavity is based on silica.

9. The micro-cavity laser of Claim 8 wherein said silica-based micro-cavity is doped with a rare earth element to provide an active medium.

10. The micro-cavity laser of Claim 9 wherein said rare earth element is at least one of erbium, ytterbium, praseodymium, neodymium, holmnium, and thulium.

11. The micro-cavity laser of Claim 1 wherein said micro-cavity optical resonator is a semiconductor, said semiconductor being arranged to be pumped electrically.

12. The micro-cavity laser of Claim 1 wherein the material composition of said micro-cavity includes phosphate glass.

13. The micro-cavity laser of Claim 1 wherein said micro-cavity optical resonator includes a plurality of micro-rings in a semiconductor.

14. The micro-cavity laser of Claim 1 wherein said micro-cavity optical resonator includes a plurality of micro-rings on an optical fiber.

15. The micro-cavity laser of Claim 1 wherein said micro-cavity optical resonator includes a plurality of photonic crystal cavities.

16. The micro-cavity laser of Claim 1 wherein said micro-cavity optical resonator is fabricated on a substrate.

17. The micro-cavity laser of Claim 1 wherein the micro-cavity optical resonator includes Bragg gratings in the resonant mode path so as to provide increased spectral purity of the lasing output.

18. The micro-cavity laser of Claim 17 wherein the Bragg gratings in the resonant mode path are defined holographically.

19. The micro-cavity laser of Claim 1 wherein the micro-cavity optical resonator has at least one preferred output frequency, and further including a frequency selector in the mode path of the micro-cavity optical resonator of at least one of the preferred output frequencies of the micro-cavity optical resonator.

20. A system for producing laser emission in a desired wavelength band, the system comprising:

a. A fiber waveguide, said waveguide having a first end and a second end and a tapered region therebetween, said tapered region having a tapered diameter;

b. A micro-cavity optical resonator, said resonator having a mode path diameter, said micro-cavity resonator being constructed from a silica material doped with at least one dopant;

c. Optical gratings, said optical gratings being position in the mode path of at least one resonant frequency of said micro-cavity optical resonator;

d. An alignment structure, said alignment structure being arranged to locate said micro-cavity optical resonator and said fiber waveguide in proximity to one another so as to enable coupling between said tapered region of said fiber waveguide and said micro-cavity optical resonator; and,

e. A laser pump, said laser pump being optically connected to said first end of said fiber waveguide and being arranged so as to launch one or more signals into said fiber

waveguide, said optical pump signals having frequencies which excite resonances in the micro-cavity optical resonator to thereby pump at least one silica dopant to induce lasing emission within a desired output frequency band of the system.

21. The system of Claim 20 wherein at least one of the laser pump source signals is in the 980 nanometer emission band.

22. The system of Claim 20 wherein the lasing emission is in the range of 1300-1600 nanometers.

23. The system of Claim 22 wherein the output of the system is used in a telecommunications application.

24. The system of Claim 20 wherein said taper section diameter and said mode path diameter are selected to provide optimal phased matching such that the coupling efficiency for pump and laser emission is maximized.

25. The system of Claim 20 wherein said fiber waveguide includes at least one additional optical resonator optically coupled thereto at the tapered section. Said at least one additional optical

resonator doped so as to enable operation as a laser and optically pumped by coupling to said fiber waveguide.

26. The system of Claim 25 wherein said fiber waveguide has at least one additional taper coupling sections therein and at least one of said additional doped resonators is coupled to at least one of said additional taper sections in said fiber waveguide.

27. The system of Claim 20 wherein the system includes at least one additional fiber waveguide, each said additional fiber waveguide is optically coupled to said micro-cavity resonator and arranged so as to permit additional laser pumping of or laser emission coupling from said micro-cavity optical resonator.

28. The laser of Claim 20 wherein said micro-cavity is a sphere, disk, ring or racetrack.

29. The system of Claim 20 wherein optical gratings increase the spectral purity of the laser emission by forcing laser oscillation at a desired frequency.

30. The system of Claim 20 wherein said dopants include at least one of erbium, ytterbium, praseodymium, neodymium, holmnium, and thulium.

31. The system of Claim 20 wherein said fiber waveguide is a panda fiber.

32. A micro-cavity laser comprising:

a. A first fiber waveguide, said first fiber waveguide having an evanescent coupling region, said evanescent coupling region being positioned between a first end and a second end of said fiber waveguide;

b. A micro-cavity optical resonator, said micro-cavity optical resonator being positioned in proximity to said coupling region of said first fiber so as to evanescently couple said fiber coupling region and said micro-cavity optical resonator, said micro-cavity optical resonator having at least one optical resonance at a desired frequency output, said micro-cavity optical resonator comprising an active medium capable of providing optical gain when excited; and

c. A laser pump, said laser pump being optically connected to said first end of said fiber waveguide for the purpose of exciting said gain medium.

33. The laser of Claim 32 wherein said micro-cavity resonator is fabricated on a chip or substrate.

34. The laser of Claim 33 wherein said fiber waveguide is an etched fiber.

35. The system of Claim 33 wherein said fiber waveguide is a D-fiber.

36. The system of Claim 33 wherein said fiber waveguide includes polished fiber half-blocks.

37. The system of Claim 33 wherein said fiber waveguide is a panda fiber.

38. The system of Claim 33 wherein said waveguide coupling section is phased matched to said resonator such that the pump coupling and laser emission collection efficiency are maximized.

39. The micro-cavity laser of Claim 33 wherein the micro-cavity optical resonator has at least one preferred output frequency, and further including frequency modifier gratings, said gratings being disposed in the mode path of the micro-cavity optical resonator of at least one of the preferred output frequencies of the micro-cavity optical resonator.

40. The micro-cavity laser of Claim 33 wherein said micro-cavity optical resonator includes at least one of a micro-disk, ring and racetrack.

41. A micro-cavity laser comprising:

a. A fiber waveguide, said waveguide having a first end and a second end and a tapered region therebetween, said tapered region having a tapered diameter;

b. A highly doped Erbium:Ytterbium phosphate silica micro-sphere, said microsphere being arranged so as to enable weak optical coupling between said microsphere and said tapered region of said fiber waveguide; and

c. A laser pump signal, said laser pump signal being transmitted in said fiber waveguide through said tapered region, said laser signal including a frequency which excites a resonance in said silica microsphere and pumps the erbium gain medium to induce laser emission.

42. A micro-cavity laser system comprising:

a. A fiber waveguide, said fiber waveguide having at least one tapered coupling region, said tapered coupling regions being located between said first end and said second end of said fiber waveguide;

b. A plurality of micro-cavity optical resonators including a first micro-cavity resonator, each said micro-cavity optical resonator being arranged in proximity to at least one of said tapered coupling regions so as to provide optical coupling between said micro-cavity optical resonator and said fiber waveguide through at least one said tapered coupling region of said fiber waveguide, at least one of said micro-cavity

optical resonators having at least one optical resonance at a desired frequency output, said first micro-cavity optical resonator including an active medium associated therewith capable of providing optical gain upon pump excitation; and

c. At least one laser pump, the output of said laser pump being optically connected to said first end of said fiber waveguide to couple optical pump power into at least said first micro-cavity resonator to excite said active medium associated with said first micro-cavity optical resonator and induce lasing action such that laser output power is coupled to said fiber waveguide.

43. The micro-cavity laser system of Claim 42 wherein the laser system includes at least a second micro-cavity optical resonator, said at least a second micro-cavity resonator including an active medium, said active medium associated with said at least a second micro-cavity optical resonator providing optical gain upon pump excitation at a frequency different than in said first micro-cavity optical resonator.

44. The micro-cavity laser system of Claim 42 wherein at least one of said micro-cavity optical resonators is one of a microsphere, disk, ring, and racetrack.

45. The micro-cavity laser system of Claim 42 wherein said micro-cavity is based on silica.

46. The micro-cavity laser system of Claim 45 wherein said silica-based micro-cavity is doped with a rare earth element to provide an active medium.

47. The micro-cavity laser system of Claim 46 wherein said rare earth element is at least one of erbium, ytterbium, praseodymium, neodymium, holmnium, and thulium.

48. The micro-cavity laser system of Claim 42 wherein said plurality of micro-cavity optical resonators are semiconductor based, said semiconductor being arranged to be pumped electrically.

49. The micro-cavity laser system of Claim 42 wherein the material composition of at least one micro-cavity resonator includes phosphate glass.

50. The micro-cavity laser of Claim 42 wherein said plurality of micro-cavity optical resonators are fabricated on a substrate.

51. The micro-cavity laser system of Claim 42 wherein said plurality of micro-cavity optical resonator includes a plurality of micro-rings on an optical fiber.

52. The micro-cavity laser system of Claim 42 wherein said plurality of micro-cavity optical resonator includes a plurality of photonic crystal cavities.

53. The micro-cavity laser system of Claim 42 wherein said plurality of micro-cavity optical resonator is fabricated on a substrate material which is a semiconductor.

54. A method of creating a laser signal of a desired frequency, the steps comprising:

Launching at least one signal into a fiber waveguide, said waveguide having a tapered coupling region, said tapered coupling region being optically coupled to a micro-cavity resonator, said micro-cavity resonator containing a gain medium and being resonant and critically coupled to the signal so as to permit excitation of the gain medium and lasing in a desired emission band.

55. A method of obtaining a laser signal within a desired frequency range, the steps comprising:

Receiving a laser signal in a waveguide, said waveguide being optically connected to a fiber waveguide, said fiber waveguide having a fiber tapered coupling region therein, said tapered coupling region being optically coupled to a micro-cavity resonator, said micro-cavity resonator having a resonance at the desired output

frequency, and said micro-cavity resonator containing a gain medium capable of amplification at the desired output frequency and excitation from the said laser signal.

56. A method of fabricating a phosphorus glass microsphere for use in a micro-cavity resonator, the steps comprising:

Melting a small piece of phosphorus glass material in a crucible,

Stabilizing the temperature of said molten phosphorus glass,

Placing the tip of a silica fiber taper into the molten phosphorus glass,

Extracting the silica fiber so that a small phosphate taper is formed on the end of the silica fiber taper;

Melting the end of the phosphate taper until a spheroid forms under surface tension,

Quickly cooling the phosphate sphere in a manner which avoids crystallization of the phosphate in the spheroid to an extent which would interfere with the refractive properties of the spheroid as a micro-cavity optical resonator.

57. The method of producing a microsphere of Claim 54 wherein said phosphorus glass material is doped with a rare earth element.

58. The method of Claim 55 wherein said dopant includes Erbium.

59. The method of Claim 55 wherein said dopant includes Ytterbium.